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EFFICIENCY ANALYSIS OF GRANULATED LIME SUBSTANCE KALKTRĄŠĖ AND ITS COMBINATION WITH HUMUS ADDITIVE IN ACID SOILS

REPORT

of precise field trials and lab analyses performed in 2013

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INTRODUCTION

Liming has been and is a key tool to adjust the reaction of acid soils in the upper and deeper layers. Change in soil reaction from strongly acidic to close to neutral activates the micro-organisms and organic matter decomposition. Inserting lime substances to strongly acidic soil increases the availability and consumption of phosphorus for the plants. When soil pH_{KCl} > 5.5 mobile aluminium which is toxic for the plants is removed from the soil solution, it is replaced by divalent calcium and magnesium ions which are important for plant development. Under their impact aggregates resistant to water and mechanical effects form, soil becomes less exposed to wind and water erosion, it increases the nutrients and organic carbon content. Taking this into account it is understandable that maintaining optimum pH in the soil plough layer and subsoil horizons is important from both soil and environment protection attitude in terms of present-day environmental variable climatic conditions.

Achieving and maintaining optimum soil reaction is of particular relevance in the context of present day's agricultural development, when it, moving away from the maximum output of production, is increasingly seeking for environmental goals: to protect water and soil from degradation. For this goal was implemented, the fertilization objective is not only to supply plants with nutrients, but also the desire to maintain the existing soil fertility and to increase of the low-nutrient level to medium (optimal) (Pecio, 2004). In the context of such claims there is no doubt that the liming system created a few decades ago needs to be adapted to existing climate and farming conditions. In the course of creation of the mentioned system important is selection of proper calcareous materials, depending on their neutralizing effect strength and existing soil pH and texture. This study is also an attempt to evaluate the granular lime substance Kalktrąšė pure (Kalktrąšė V) and with humic additive (Kalktrąšė hum) which recently entered Lithuanian market from various aspects.

Aim of the study is to explore efficacy of granular lime Kalktrąšė and its combination with humus in the acidic becoming soils in the West Lithuania climatic conditions.

Tasks:

1. To find out Kalktrąšė's (pure and with humic additive) effect on soil pH_{KCl} and other acidity indicators and biogenic elements, depending on the used rate, fraction size and duration;
2. To evaluate effect of varying intensity maintenance liming with Kalktrąšė (pure and with humic additive) on productivity of spring cereals and perennial grasses;
3. To establish spreading uniformity of different factions of Kalktrąšė with the means of centrifugal type fertilizer spreaders;

   To base scientifically Kalktrąšė usability opportunities to achieve and maintain optimum soil pH.

1. LITERATURE REVIEW

In soil and environmental terms soil acidification is one of the main problems, both in Europe and Lithuania. This is one of the soil chemical degradation forms, reducing its fertility and ecological stability (Varallyay, 2000; Lošak et al., 2012; Szymanka et al., 2008). Nutrients and their availability to plants, micro-organism populations species composition, quantity and activity, organic matter disarrangement, carbon and nitrogen immobilization in soil, leaching of these elements and emissions into the atmosphere and eventually plant development and productivity are directly dependent on the soil pH indicator (Mažvila et al, 2011; Karlik, 1995). The vast majority of researches in Lithuania and abroad, emphasized that the first and most effective measure, neutralizing acidity, is insertion of calcareous substances containing Ca^{+2} and Mg^{+2} cations into the soil, into this very complex multicomponent environment with finite operating limit and spatial configurations (Kibblewhite et al, 2008). In this framework liming process is seen as having a mixed impact on the soil: from improving the yield, quality and plant productivity (Scott, 1999; Pierce and Warncke, 2000; Ossom and Rhykerd, 2008; Eidukevičienė et al, 2010; Lande et al, 2012) to deterioration of some of its essential properties. Studies in Poland have shown that under influence of liming, mineral and total nitrogen, phosphorus and organic matter decreased in the soil (Bednarek and Reszka, 2008; Otabbong et al, 1993). Literary evidence suggests that in the wide range of soil properties change due to liming, critical importance belongs to the existing soil pH, depending on whether the lime is inserted for the first time, or liming has already become systematic.

The concept of liming as a long-term process is especially profound in Sweden, Poland, the Czech Republic, the USA and Australia. In these countries, liming is carried out with precision: this means the appropriate chemical composition and lime grit are selected, their contents are counted, the most uniform pouring way and the best time are selected according to the current state of the soil, its chemical, mineralogical and textural composition, (Pagani and Mallarino 2012; Lalande et al, 2009). In Lithuania it was not separated between whether the soil liming was performed for the first time or it has become periodic. Soils for about three decades (1964 to1994) were systematically limed (every 5-7 years) with the same intensity (5-7 t/ha) traditionally with the use of liming materials: dusty limestone (Mažvila, 2010). Thanks to such long-term intensive liming, relatively acid soil ($pH \leq 5.0$) area was reduced to 18.6 %, including very acid to 1.5 %, and moderately acid to 9 %. The result achieved in terms of soil improvement has not been preserved, since from 1997 soils are no longer limed, which led to repeated soil acidification, mediated by precipitation abundance, use of physiologically acid fertilizers and elimination of base cations with the yield. Lately in Lithuania acidic soils ($pH \leq 5.5$) take about 66.5 % of the total area of soil. Most (31.3 %) of the soils are located in the western part of Lithuania, during the last decade their area has increased by 15-21 % (National Rural Development Strategy 2007-2013, 2007). These re-acidified soils have priority in relation to liming and their current chemical state (relatively many exchangeable cations, still small exchangeable acidity, few mobile Al from 0.42 to 1.76 mEq kg^{-1}) significantly different from naturally acidic soil, requires a suitable i.e. adapted to current weather conditions liming system. According to Polish scientific studies, soils with a pH between 5.1 and 5.5 are already in the acidification risk area and they must be subjected to supportive liming at regular intervals, depending on the level of soil acidification (Pecio, 2004). In the soil, where in the upper 0-10 cm layer for many years reaction pH of 5.5 is maintained, the value of this indicator is slowly increasing as well as in the 15-20 cm layer (Upjohn et al, 2005). For the soil where optimal reaction is maintained, various additives efficient in terms of soil's health improvement are used, the most important of them are humates (humic acids). Calcium humate as a colloidal nature material improves soil structure, aggregate stability, increases the amount of exchangeable cations of the soil and biota population (Donald, 2010). According to Japanese scientists data, insertion of humates, organic - inorganic fertilizer additives featuring multifunctional properties into the soil, influences the increasing soil fertility and efficiency of use of nitrogen and phosphorus fertilizer (Wang, 2007). Synergistic effect of humic acids to mineral fertilizers was established. Efficiency of the additives use in the soil is highly dependent on the soil group characteristics and inserted volumes (Vacha et al, 2002; Hao Qing et al, 2012)

2. RESEARCH METHODS

2.1. Location and subject of the study

Location of the study: the research was performed in the rotational field of Lithuanian research centre for agriculture and forestry Vėžaičiai branch (LAMMC) (Western Lithuania, Seaside lowland eastern edge 55°43'N, 21°27'E).

Subject of the study: granulated liming substance ***Kalktrąšė V*** of various fractions (∅ 0,01-2 mm and ∅ 2-5 mm) with the following chemical composition: CaO > 43,0 % ($CaCO_3$ > 77 %); MgO > 2,5 %; Fe_2O_3 > 1,0 %; K_2O > 1,9 %; Na_2O > 0,6 % SO_3 > 2,4 %.

Granulated liming substance ***Kalktrąšė Hum*** of various fractions (∅ 0,01-2 mm, ∅ 2-5 mm and ∅ 5-10 mm) with the following chemical composition: CaO > 43,0 % ($CaCO_3$ > 77 %); MgO > 2,5 %; Fe_2O_3 > 1,0 %; K_2O > 2,8 %; Na_2O > 0,6 % SO_3 > 2,4 %; humus – 0,5 %.

2.2. Conditions and methods of the research

The tested soil is medium cultured: Dystric Albeluvisol (JIn). Arable layer of the soil is 20 - 28 cm thick, silty clumpy, light and medium loam (clay fraction < 0,002 mm makes 14-15 %).

In order to assess liming efficiency, in the moraine loam soil three precision field trials are performed.

<u>Trial 1.</u> In order to find effect of various intensity liming with Kalktrąšė Hum (various fraction mixtures and their volume) on the soil properties and spring barley productivity, the trial was done according to the following scheme:

1. Unlimed
2. Limed, 1 t ha^{-1} Kalktrąšė Hum mixture (50 % ∅ 0,1-2,0 mm +50 % ∅ 2,0-5,0 mm)
3. Limed, 2 t ha^{-1} Kalktrąšė Hum mixture (50 % ∅ 0,1-2,0 +50 % ∅ 2,0-5,0 mm)
4. Limed with Kalktrąšė Hum 2 t ha^{-1} (∅ 5,0-10,0 mm)

The first trial was set in 2013. Soil is of medium acidity, with pH_{KCl} 4,90 ± 0,17, hydrolytic acidity 33,32 ± 3,35 mekv. kg^{-1} and already containing small amount of mobile Al which is toxic for the plants, small amount of exchange Ca and exchange Mg (Table 1).

Table 1. Chemical characteristic of the soil before setting the trial (Trial 1), 2013

Agrochemical index	$\bar{x} \pm S\bar{x}$	Coefficient of variation (V %)
pH_{KCl}	4,90 ± 0,17	6,12
Mobile Al, mg kg^{-1}	1,43 ± 1,20	145,05
Hydrolytic acidity, mekv. kg^{-1}	33,32 ± 3,35	17,42
Exchange Ca, mg kg^{-1}	1051 ± 63,4	10,44
Exchange Mg, mg kg^{-1}	100 ± 13,0	22,54
Mobile P_2O_5, mg kg^{-1}	68 ± 6,28	18,39
Mobile K_2O, mg kg^{-1}	165 ± 6,49	7,87
Summary N, %	0,13 ± 0,0019	3,83
Organic C, %	1,26 ± 0,023	1,51

Note. $\bar{x}$ – mean; $\pm S\bar{x}$ – deviation from the mean

Trial soil is low in phosphorus, contains potassium in terms of mobile potassium, average in nitrogen, containing medium contents of organic carbon. Coefficient of variation varies in a wide range between 0,10 and 22,54. Variation of mobile aluminium is very high (V=145,05 %), because its contents in the soil varies from 0 mg kg^{-1} to 3,81 mg kg^{-1}.

Kalktrąšė Hum was applied in two rates: 1 t ha^{-1} and 2 t ha^{-1} making the mixture in equal parts (50 % each) from fine (∅ 0,1-2,0 mm) and coarse (∅ 2,0-5,0 mm) fractions as well as extremely coarse fraction (∅ 5,0-16,0 mm) at the rate of 2,0 t ha^{-1}.

Spring barley *Ūla* was grown. Trial field patches were allocated at random, in four repetitions.

***<u>Trial II.</u>* In order to find effect of various intensity (different rates) liming with Kalktrąšė Hum on soil properties and productivity of perennial grasses** study was carried out according to the following scheme:

1. Unlimed;
2. Limed with 0,5 t ha^{-1} Kalktrąšė Hum granulated (∅ 2,0 - 5,0 mm);
3. Limed with 1 t ha^{-1} Kalktrąšė Hum granulated (∅ 2,0 - 5,0 mm).

The second trial was set in 2012. Soil has low acidity with pH_{KCl} 5,13 ± 0,03, hydrolytic acidity 31,38 ± 1,71 mekv. kg^{-1}, low in mobile Al and exchange Ca and exchange Mg (Table 2). Trial soil is low in phosphorus, average in potassium, low in nitrogen, containing very little mobile sulphur and average organic carbon. In terms of these agrochemical properties, the test soil is heterogeneous, coefficient of variation varies in a wide range from 0,98 to 91,77 %.

Table 2. Chemical characteristic of the soil before setting the trial (Trial II) 2012.

Agrochemical index	$\bar{x} \pm S\bar{x}$	Coefficient of variation (V %)
pH_{KCl}	5,13 ± 0,03	1,12
Mobile Al, mg kg^{-1}	1,6 ± 0,85	91,77
Hydrolytic acidity, mekv. kg^{-1}	31,38 ± 1,71	9,45
Exchange Ca, mg kg^{-1}	1127 ± 25,69	3,95
Exchange Mg, mg kg^{-1}	117 ± 0,67	0,98
Mobile P_2O_5, mg kg^{-1}	64,7 ± 2,03	5,43
Mobile K_2O, mg kg^{-1}	153 ± 6,89	7,78
Summary N, %	0,11 ± 0,01	17,50
Mobile S, %	0,81 ± 0,18	38,18
Organic C, %	1,21 ± 0,13	19,12

Note. $\bar{x}$ – mean; $\pm S\bar{x}$ – deviation from the mean

For liming granulated liming substance Kalktrąšė Hum was used, granule size 2,0-5,0 mm. Liming rates were 0,5 t ha^{-1} and 1 t ha^{-1}. Liming was done in the spring of 2012 before sowing barley with perennial grasses undercrop.

In the spring (2013) during plant vegetation restoration, it was repeatedly limed according to the scheme in the same rates like in 2012. Test field patches were allocated at random, in four repetitions.

***<u>Trial III.</u>* In order to find duration of effect of Kalktrąšė V (of various coarseness fractions) in the agroecosystem,** the continued trial (from 2009) is done according to the following scheme:

1. Unlimed;
2. Limed, 0,5 rate Kalktrąšė V granulated (∅ 0,01 - 2,0 mm);
3. Limed, 1,0 rate Kalktrąšė V granulated (∅ 0,01 - 2,0 mm);
4. Limed, 0,5 rate Kalktrąšė V (∅ 2,0 - 4,0 mm);
5. Limed, 1,0 rate Kalktrąšė V granulated (∅ 2,0 - 4,0 mm).

The third trial was set in 2009. Soil is very acid, pH_{KCl} 4,46, high in mobile Al which is toxic for the plants, with high hydrolytic acidity and low in exchange Ca and exchange Mg (Table 3). The test soil is medium in phosphorus, high in potassium, medium in nitrogen, with average amount of organic carbon. In terms of these chemical properties, the test soil is heterogeneous, because coefficient of variation varies in a wide range from 0,10 to 21,81.

Table 3. Chemical characteristic of the soil before setting the trial (Trial III), 2009

Agrochemical index	$\bar{x} \pm S\bar{x}$	Coefficient of variation (V %)
pH_{KCl}	4,46 ± 0,02	1,19
Mobile Al, mg kg^{-1}	63,9 ± 4,41	21,81
Hydrolytic acidity, mekv. kg^{-1}	59,6 ± 1,18	6,25
Exchange Ca, mg kg^{-1}	654 ±3 7,5	18,15
Exchange Mg, mg kg^{-1}	160 ± 2,75	5,44
Mobile P_2O_5, mg kg^{-1}	139 ± 3,50	3,57
Mobile K_2O, mg kg^{-1}	204 ± 4,00	2,77
Summary N, %	0,14 ± 0,001	0,10
Organic C %	1,29 ± 0,04	4,39

Note. $\bar{x}$ – mean; $\pm S\bar{x}$ – deviation from the mean

The trial is continued, performed in the rotation chain spring barley → winter wheat → perennial grasses I n.m. → fallow → winter rape. Liming was done using two different fraction granulated liming substances Kalktrąšė V, with granule size 0,01 - 2,0 mm (fine fraction) and 2,0 - 5,0 mm (coarse fraction) diameter. Liming was done at rates 0,5 and 1,0 according to soil's hydrolytic acidity. With 0,5 rate of Kalktrąšė 3,5 t ha^{-1} of pure $CaCO_3$ was spread, total physical weight of the substances was 4,5 t ha^{-1}. With 1,0 rate 7,0 t ha^{-1} of pure $CaCO_3$ was spread, physical weight of 9,0 t ha^{-1} of lime substances. It was limed once (in 2009), in later years lime substance effect analyses were performed.

Since 2009 for the plants grown in rotation tillage-free technology was applied, since 2013 traditional tillage was applied. This year, when the second year's red clover poorly survived winter, the test area was prepared for sowing of winter oilseed rape: it was disked twice, the test area was ploughed, cultivated, fertilizer was scattered in all directions and winter rape was sown. Test fields were randomized, with four replications.

Agroclimatic conditions. Meteorological (air temperature and rainfall) data is given in table 4. Spring of 2013 was late, active vegetation of the plants started on 21 April. Monthly average air temperature of May was 14,3 °C or by 3,1°C higher than the standard climatic rate (SKN). In the first decade of May dry weather prevailed, largest rainfall was in the third decade. Rainfall of the month was 49,3 mm close to SKN. Average soil temperature at 15-20 cm depth in the third decade of May varied from 13,2 to 14,7 °C. Monthly average air temperature of June was 17,5 °C, with as little rainfall as 9,0 mm. The second decade was very dry: average air temperature was 16,0 °C, rainfall 8,2 mm. On 23 and 24 of June torrential rainstorms happened bringing 43,2 mm. Total rainfall in June was 77,5 mm (121 % of the rate), and average temperature was 18,2 °C. In June warmth and precipitation conditions for the plants to grow were just average, because precipitation distributed very unevenly. In July warm weather prevailed. Average air temperature was 17,4 °C, rainfall 113,1 mm or 126 %

SKN. In the first decade of July dry weather prevailed, air temperature of the second decade was 17,6 °C rainfall 25,0 mm. Extremely torrential rainstorm happened on 30 July with 77,8 mm of rainfall. In August average air temperature was 17,1°C, rainfall 71,0 mm, or 75 % of the rate, and its larger part (53,7 mm) fell during the second decade. In two decades of September weather was warm and wet, in the third it cooled, was little rainfall. September with regard to temperatures and rainfalls was close to SKN (monthly average temperature was 11,9 °C, rainfall 90,6 mm).

Table 4. Meteorological data of Vėžaičiai simple climatic station, 2013.

Months	Average air temperature, °C					Rainfall, mm				
	Decades			Average monthly	Average multiannual air temperature 1947-2012	Decades			Sum per month	Average multiannual rainfall rate 1947-2012
	I	II	III			I	II	III		
April	-0,1	6,9	7,0	**4,6**	5,8	16,7	14,5	19,2	**50,4**	41,1
May	12,0	15,7	15,2	**14,3**	11,2	3,0	10,5	35,8	**49,3**	44,3
June	17,5	16,0	18,2	**17,2**	14,8	9,0	8,2	60,3	**77,5**	63,6
July	16,9	17,3	18,1	**17,5**	17,0	14,3	17,2	81,6	**113,1**	90,0
August	19,6	16,8	15,0	**17,1**	16,5	14,5	53,7	2,8	**71,0**	94,9
September	13,9	13,6	8,3	**11,9**	12,4	44,3	34,8	11,5	**90,6**	94,2

Laboratory analysis methods:

pH in 1 mol/l KCl suspension – ISO 10390:2005.

Hydrolytic acidity – Kappen's method.

Mobile aluminium (Al) – Sokolov method – ISO11260 and ISO14254;

Mobile calcium (Ca) and mobile (Mg) – LVP D-13:2011, revision 1. Buffer solution pH 3,7.

Summary nitrogen (N) – Kjeldahl method – ISO 11261-1995.

Organic carbon (C) – ISO 10694:1995.

Mobile phosphorus (P_2O_5) and mobile potassium (K_2O) concentration – LVP D-07:2012, revision 4. Laboratory-prepared Egner-Rim-Doming (A-L) method.

Soil microbiological analyses: mineral nitrogen assimilating micro organisms, total count of bacteria, count of fungi, count of sporulated bacteria, soil respiration (CO_2) and C:N ratio.

Soil moisture is measured by weighing method.

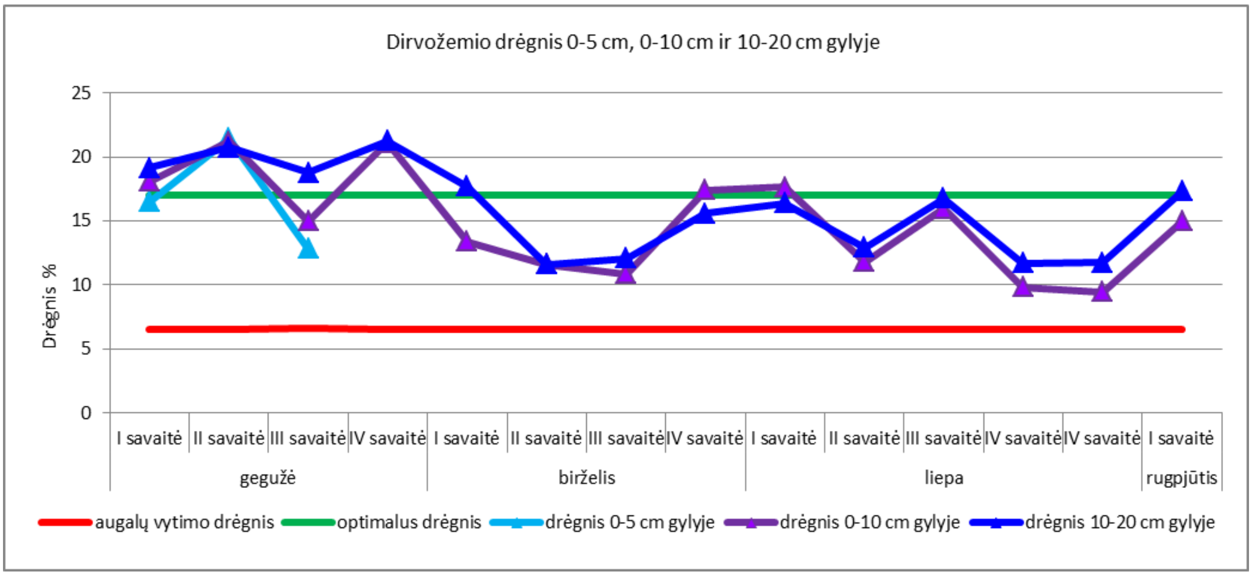
The analyses were carried out by field precise test and laboratory analysis methods. Soil chemical analyses were performed using standardized methods in LAMMC Agrochemical Research Centre Lab. Soil micro biologic analyses, soil moisture, photometric analyses of plants were performed in LAMMC Vėžaičiai branch.

Research data statistic evaluation was done using the statistical package ANOVA (Tarakanovas, Raudonius, 2003). The least significant difference limit between the options was presented R_{05}.

3. RESEARCH RESULTS

3.1. Soil moisture during plant vegetation

Soil moisture has a significant impact on the development of plants. Also with sufficient moisture content in the soil conditions favourable for the liming materials and mineral fertilizers moved to the soil sobbed complex are created. For barley, winter triticale to grow optimal moisture of medium heavy loam arable soil is 17-18 %. Optimal soil moisture in medium heavy loam soil is 19-23 % (excess moisture > 29 %, wet 24-28 %, optimal 13-18 %, droughty 7-12 %, very dry < 7 %). During the plant vegetation period soil moisture in the arable layer varied in a quite wide range from 8,7 % to 21,3 % at 0-10 cm depth (fig. 1).



Soil moisture at 0-5 cm, 0-10 cm and 10-20 cm depth

Moisture, per cent

Week I Week II Week III Week IV Week I Week II Week III Week IV Week I Week II Week III Week IV Week IV Week I

May June July August

Plant wilting humidity Optimum moisture Moisture at 0-5 cm depth Moisture at 0-10 cm depth Moisture at 10-20 cm depth

Fig.1. Soil moisture during plant vegetation, Vėžaičiai, 2013.

Soil arable layer moisture of spring barley and perennial grasses during vegetation period is given on fig. 2. During barley germination, soil moisture contents at 0 - 5 cm depth varied from 14,5 % to 21,52 %, at 0-10 cm depth – 16,17 to 21,52 %, at 10 - 20 cm depth moisture varied even less: 19,08 to 19,94 %. Moisture conditions for barley germination, perennial grasses growing were just average. Only later, from the beginning of barley tillering till the end of earing soil moisture both at 0 - 10 cm, and 10-20 cm depth varied 13,65 to 21,76 % near the optimal rate, i.e. 17 %. When barley was at BBCH 71 stage, moisture at 0-10 cm and 10-20 cm depth was reduced respectively down to 8,65 % and 11,64 %, however this reduction did not make very negative impact on barley development. Soil moisture was reduced most of all – down to 4,5 % and 6,96 % when barley was in the late milk stage. Throughout barley vegetation period and for the perennial grasses till harvesting conditions in respect to soil moisture were at an average favourable for the lime substances and fertilizers to move into the soil solution. Perennial grass and spring barley productivity data is given in the following sections.

3.2. Effect of different intensity liming with Kalktrąšė Hum on soil properties and spring barley productivity

One-time insertion of lime substance Kalktrąšė Hum of different coarseness (∅ 0,1-2,0 mm ∅ 2,0-5,0 mm, ∅ 5-10 mm) and at different rates (1 t ha^{-1} and 2 t ha^{-1}) (according to 1st trial scheme) after expiration of 4 months did not have essential impact on soil acidity indicators. All these indicators varied within tolerance limits both in terms of pH (pH_{KCl} – 4,97-5,13), hydrolytic acidity (35,6-41,32 mekv. kg^{-1}), and mobile aluminium (0,91-2,12 mg kg^{-1}) (table 5).

Table 5. Effect of liming with various fraction mixture rates Kalktrąšė Hum on pH_{KCl}, hydrolytic acidity and mobile Al

Option	pH_{KCl}	Hydrolytis acidity mekv. kg^{-1}	Mobile Al, mg kg^{-1}
1. Unlimed	5,07	35,6	1,07
2. Kalktrąšė Hum 1 t ha^{-1} (50 % 0,1-2,0 +50 % 2,0-5,0)	4,97	41,32	2,12
3. Kalktrąšė Hum 2 t ha^{-1} (50 % 0,1-2,0 +50 % 2,0-5,0)	5,13	37,84	0,91
4. Kalktrąšė Hum 2 t ha^{-1} (5,0-10,0)	5,03	39,50	0,91
R_{05}	0,47	10,743	3,903

After Kalktrąšę Hum insertion, exchange calcium and exchange magnesium increasing trend was detected. Compared with unlimed soil, exchange Ca grew up to 1030,3-1054,7 mg kg^{-1} (table 6).

Table 6. Effect of liming with various fraction mixture rates Kalktrąše Hum on exchange Ca and exchange Mg

Option	Exchange Ca, mg kg^{-1}	Exchange Mg, mg kg^{-1}
1. Unlimed	980,0	56,3
2. Kalktrąšė hum 1 t ha^{-1} (50 % 0,1-2,0 +50 % 2,0-5,0)	1030,3	63,0
3. Kalktrąšė hum 2 t ha^{-1} (50 % 0,1-2,0 +50 % 2,0-5,0)	1054,7	60,7
4. Kalktrąšė hum 2 t ha^{-1} (5,0-10,0)	1030,7	63,7
R_{05}	280,841	15,190

One-time insertion of liming substances Kalktrąšė Hum did not affect barley germination. In unlimed soil number of germinated plants was found 266 pcs m^{-2} (table 7). Number of productive stems varied within tolerance limits 604 - 685 pcs m^{-2}. Total largest number of (productive and non-productive) stems (708,5-721,0 pcs m^{-2}) was found in the soil limed at 2 t ha^{-1} rates. Liming did not affect stem height, it varied from 53,18 cm to 55,13 cm.

Table 7. Effect of liming with various fraction mixture rates Kalktrąše Hum on number and height of germinated spring barley and their stems

Options	Number of germinated plants, pcs 1 m^{-2}	Productive	Total	Stem height, cm
		number of stems pcs 1 m^{-2}		
1. Unlimed	266,0	668,5	691,5	54,40
2. Kalktrąšė Hum 1 t ha^{-1} (50% 0,1-2,0 + 50 % 2,0-5,0)	261,0	604,0	662,5	53,18
3. Kalktrąšė Hum 2 t ha^{-1} (50% 0,1-2,0 + 50 % 2,0-5,0)	277,5	676,5	708,5	55,13
4. Kalktrąšė Hum 2 t ha^{-1} (5,0-10,0)	296,5	685,0	721,0	54,28
R_{05}	63,719	106,65	117,68	5,786

Insertion of liming substances had insignificant impact on the length of barley ears, grain number per ear and mass per 1000 grains (table 8). Longer ears were found after liming with 1 and 2 t ha^{-1} rates of various fraction mixtures of Kalktrąšė Hum. Number of grains per ear and mass of 1000 grains was higher in at every rate limed soil, compared with unlimed, however in all the cases no statistically significant differences were established.

Table 8. Effect of liming with various fraction mixture Kalktrąše Hum on the length of barley ears, grain number per ear and mass per 1000 grains

Options	Ear length, cm	Number of grains per ear, pcs	Mass of 1000 grains, g
1. Unlimed	6,50	19,73	48,46
2. Kalktrąšė Hum 1 t ha^{-1} (50 % 0,1-2,0 + 50 % 2,0-5,0)	6,53	21,18	48,56
3. Kalktrąšė Hum 2 t ha^{-1} (50 % 0,1-2,0 + 50 % 2,0-5,0)	6,60	20,18	48,88
4. Kalktrąšė Hum 2 t ha^{-1} (5,0-10,0)	6,28	20,28	48,75
R_{05}	0,542	1,977	1,455

During the trial all used rates and fractions of Kalktrąšė Hum resulted in larger barley harvests compared with unlimed soil (table 9). Statistically significant growth of harvest volume + 0,87 t ha^{-1} was obtained after having limed with Kalktrąšė Hum at the rate 2 t ha^{-1} of mixture of different fractions. Although minor, but increase in the harvest was obtained (0,72 t ha^{-1}) with lower rate of Kalktrąšė Hum fraction mixture (1 t ha^{-1}), as well as harvest increase was obtained (0,78 t ha^{-1}) with the largest (∅ 5,0-10,0 mm) (2 t ha^{-1}) rate.

Table 9. Effect of liming with various fraction mixture Kalktrąšė Hum on spring barley harvest

Options	Grain harvest		Growth in grain t ha^{-1} compared with the control
	t ha^{-1}	%	
1. Unlimed	4,48	100	–
2. Kalktrąšė Hum 1 t ha^{-1} (50 % 0,1-2,0 +50 % 2,0-5,0)	5,20	116	+ 0,72
3. Kalktrąšė Hum 2 t ha^{-1} (50 % 0,1-2,0 +50 % 2,0-5,0)	5,35*	119	+ 0,87
4. Kalktrąšė Hum 2 t ha^{-1} (5,0-10,0)	5,26	117	+ 0,78
R_{05}	0,810	–	–

* – data is significant at 95 % probability level

3.3. Effect of annual liming with varying rates of Kalktrąšė Hum on soil properties and perennial grass productivity

After plant vegetation resumption, they were limed once more according to 2nd trial scheme with the same rates of Kalktrąšė Hum. Soil samples were taken before grass-plot discing, i.e. 4 months after liming. Soil analysis showed that soil pH remained unchanged (pH_{KCl} 5,1) (table 10). Small trend in exchange Ca and exchange Mg growth was found as well as reduction trend in hydrolytic acidity, compared with unlimed soil.

Soil analysis according to the plant nutrient changes found that mobile P_2O_5 grew up to 74,3 ± 3,00 mg kg^{-1}, and mobile K_2O grew up to 191,3 ± 7,18 mg kg^{-1}.

Table 10. Effect of liming with various rates of Kalktrąšė Hum on agrochemical indicators

Option	pH_{KCl}	Hydrolytic acidity mekv. kg^{-1}	Exchange Ca, mg kg^{-1}	Exchange Mg, mg kg^{-1}
1. Unlimed	5,10	37,49	935,8	67,8
2. Kalktrąšė Hum 0,5 t ha^{-1} (∅ 2,0-5,0 mm)	5,15	35,30	1004,5	71,5
3. Kalktrąšė Hum 1 t ha^{-1} (∅ 2,0-5,0 mm)	5,10	36,58	927,8	77,5
R_{05}	0,20	8,946	204,557	26,016

Perennial grass yield was calculated as dry matter (SM) t ha^{-1}. Perennial grass yield was of average (3,63-3,85 t ha^{-1}) size, because precipitation during the intense plant growth period in May and June was distributed very unevenly (table 11). In limed soil, compared with unlimed, small increase of SM yield 0,02-0,22 t ha^{-1} of perennial grass was obtained, however no statistically significant extra yield was found. Red clover is sensitive to soil acidity, compared with timothy, so clover positively responds to liming. Largest number of red clover (30,5-48,4 %) was obtained in the repeatedly limed soil and smallest in unlimed soil (22,3 %).

Table 11. Effect of liming with various rates of Kalktrąšė Hum on yield and botanical composition of perennial grasses (SM)

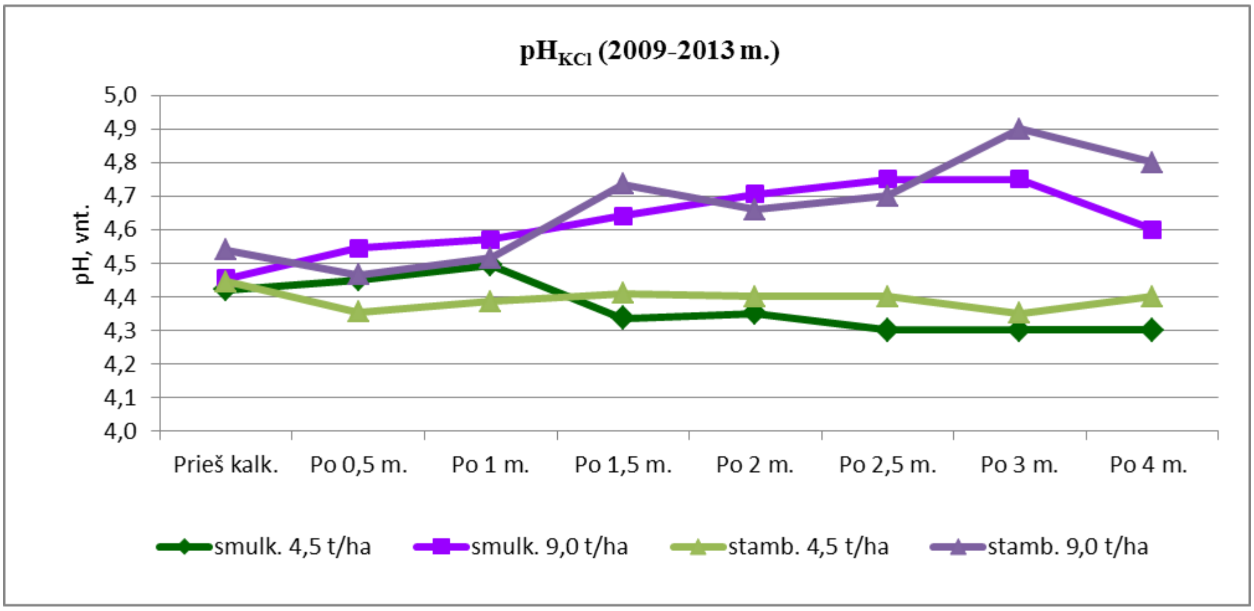
Option	SM yield, t ha^{-1}	Botanical composition		
		Clover, %	Timothy, %	Forbs, %
1. Unlimed	3,63	22,3	77,5	0,2
2. Kalktrąšė Hum 0,5 t ha^{-1} (∅ 2,0-5,0 mm)	3,65	30,5	69,1	0,4
3. Kalktrąšė Hum 1 t ha^{-1} (∅ 2,0-5,0 mm)	3,85	48,4	48,7	2,9
R_{05}	1,032	25,509	27,715	0,568

Basing on the research data, annual yield of red clove dry matter in the limed soil was 1,4 - 2,2 times larger than in unlimed.

3.4. Duration of Kalktrąšė V effect on soil's agrochemical indicators

After liming, for three years in the rotation, the simplified (without ploughing) cultivation technology was applied, on the fourth year it was ploughed. The test soil (in 2013) in terms of plant nutrients, was optimum for the plants to grow, rich in phosphorus: mobile P_2O_5 158 ± 14,0 mg kg^{-1} and high potassium: mobile K_2O 239 ± 12,5 mg kg^{-1}.

Changes in the soil pH_{KCl} throughout four years are shown on fig. 2.

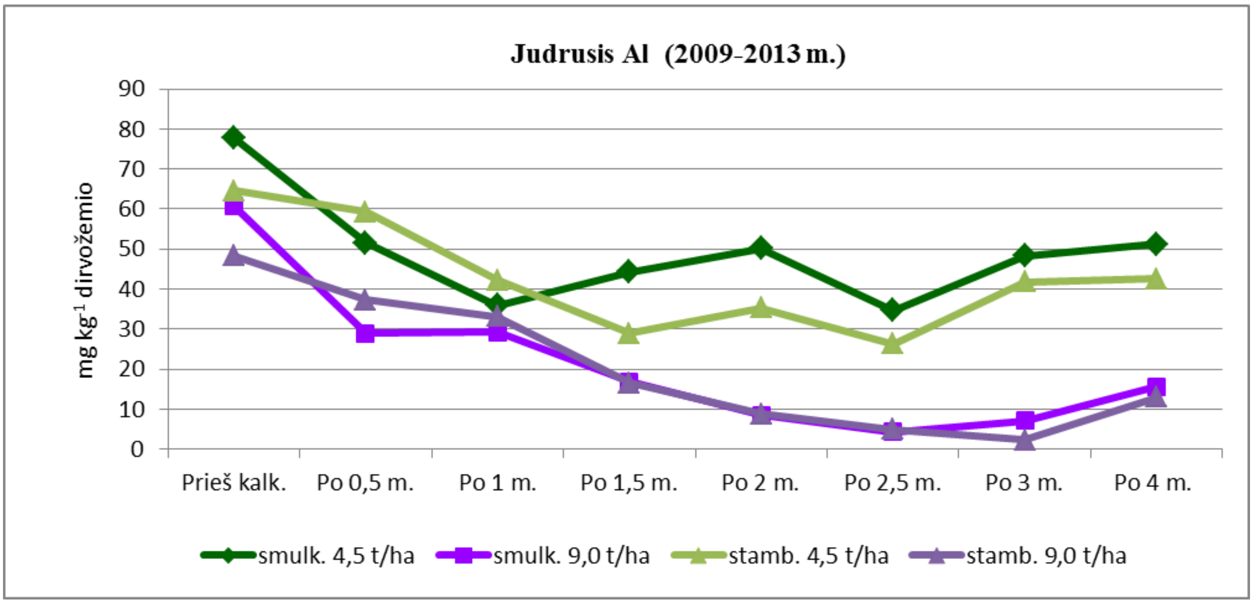


Before liming After 6 months After 1 year After 1.5 year After 2 years After 2.5 year After 3 years After 4 years
fine 4.5 t/ha fine 9.0 t/ha coarse 4.5 t/ha coarse 9.0 t/ha

Fig. 2. Effect of Kalktrąšė V on the changes in soil pH_{KCl}

Six months after insertion of Kalktrąšė V, pH_{KCl} grew a little, by 0,03-0,09. One year after liming pH_{KCl} increase was by 0,1 in the soil, limed with both rates of fine fraction: the less one (4,5 t ha^{-1}) and the larger one (9,0 t ha^{-1}). Two years after liming pH_{KCl} most of all increased most of all thanks to the larger rate of Kalktrąšė V with both fine and coarse fractions, pH_{KCl} change was 4,5 to 4,7. After three years both fraction large rate of Kalktrąšė V resulted in pH_{KCl} increase up to 4,8-4,9, the small rates resulted in pH_{KCl} remaining the same 4,3-4,4. After 4 years pH_{KCl} in the soil limed with both fraction larger rates slightly reduced down to 4,6-4,8, and in the soil limed with the smaller rates pH_{KCl} did not change, remaining the same 4,3-4,4.

Contents of mobile aluminium in the soil reduced fastest in the soil with both lower and larger rates of fine fraction Kalktrąšė V rate (fig. 3). Six months after liming mobile Al decreased correspondingly from 77,7 to 51,6 mg kg^{-1} and from 60,7 to 28,9 mg kg^{-1}. One year after liming reduction in the mobile Al was found from use of the both rates coarse fraction Kalktrąšė V. After two years it was established that mobile Al in the soil limed wit the large (9 t ha^{-1}) rate of Kalktrąšė V both fine (0,01-2,0 mm) and coarse (2,0-4,0 mm) fractions reached the level which is non-harmful for the plants, respectively 8,5 and 8,9 mg kg^{-1}. Where limed with the lower rates of the both fractions, mobile Al remains at the levels harmful for the plants: 50,1 and 35,2 mg kg^{-1}. After three years thanks to larger rates of Kalktrąšė V mobile Al reduced down to 2,3 - 7,0 mg kg^{-1}, and remained at the same level 48,3 - 41,8 mg kg^{-1} thanks to smaller rates. Four years after liming and ploughing, it was found that in the soil, limed with larger rates of Kalktrąšė V mobile Al grew up to 13,0 – 15,6 mg kg^{-1}, and in the soil limed with the smaller rates it remained almost unchanged: 51,3 - 42,5 mg kg^{-1}. But this increase was not significant.



Mobile Al (2009-2013)

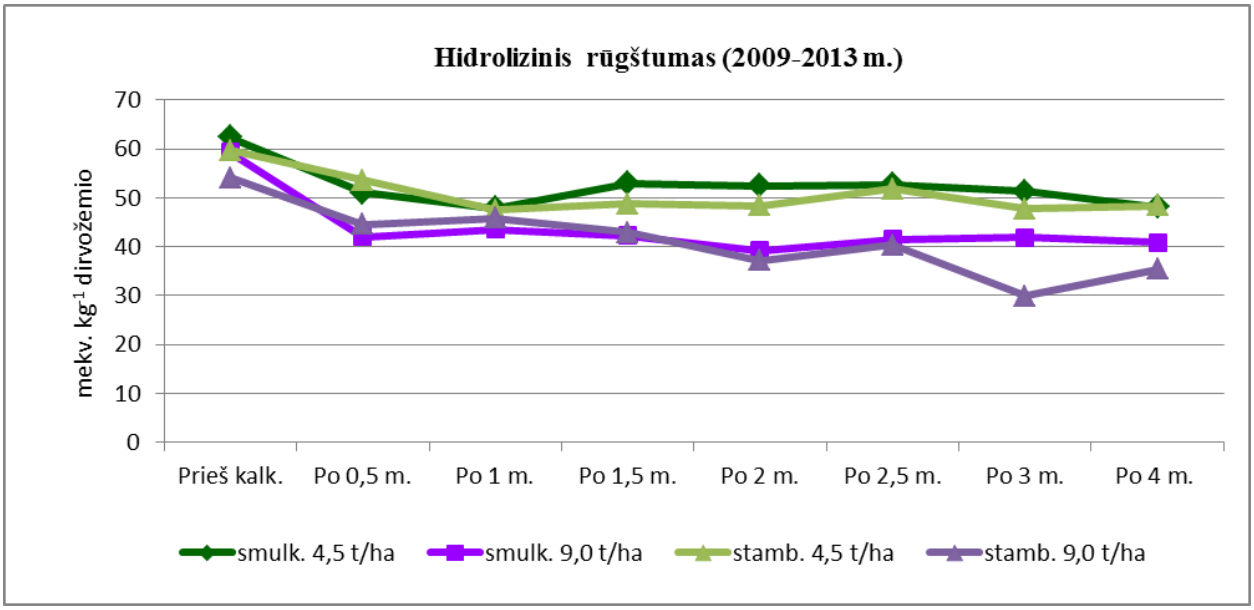
mg kg^{-1} of soil

Before liming After 6 months After 1 year After 1.5 year After 2 years After 2.5 year After 3 years After 4 years

fine 4.5 t/ha fine 9.0 t/ha coarse 4.5 t/ha coarse 9.0 t/ha

Fig. 3. Effect of Kalktrąšė V on the changes in mobile Al contents

After liming hydrolytic acidity of the soil reduced similarly with the mobile aluminium (fig. 4). Two years after liming with fine and coarse fraction smaller rate of Kalktrąšė V, hydrolytic acidity reduced from 59,4 - 62,4 mekv. kg^{-1} to 48,3-52,5 mekv. kg^{-1}. Thanks to the larger rate of the both fractions, hydrolytic acidity reduced even more to 37,1 - 39,2 mekv. kg^{-1}. Three years after applying larger rates of Kalktrąšė V hydrolytic acidity reduced as follows: thanks to fine fraction to 41,9 mekv. kg^{-1}, coarse fraction to 29,9 mekv. kg^{-1}. Hydrolytic acidity thanks to the small rate fine fraction reduced to 51,3 mekv. kg^{-1}, thanks to the coarse to 47,8 mekv. kg^{-1}. After four years, when the soil was ploughed, hydrolytic acidity in the soil remained almost unchanged. In the soil limed with larger rates of Kalktrąšė V hydrolytic acidity increased up to 35,4 - 40,8 mekv. kg^{-1}, and where the lower rates were applied it remained almost the same: 48,1 - 48,4 mekv. kg^{-1}. However such increase did not play the essential role.



Hydrolytic acidity (2009-2013)

mekv. kg^{-1} of soil

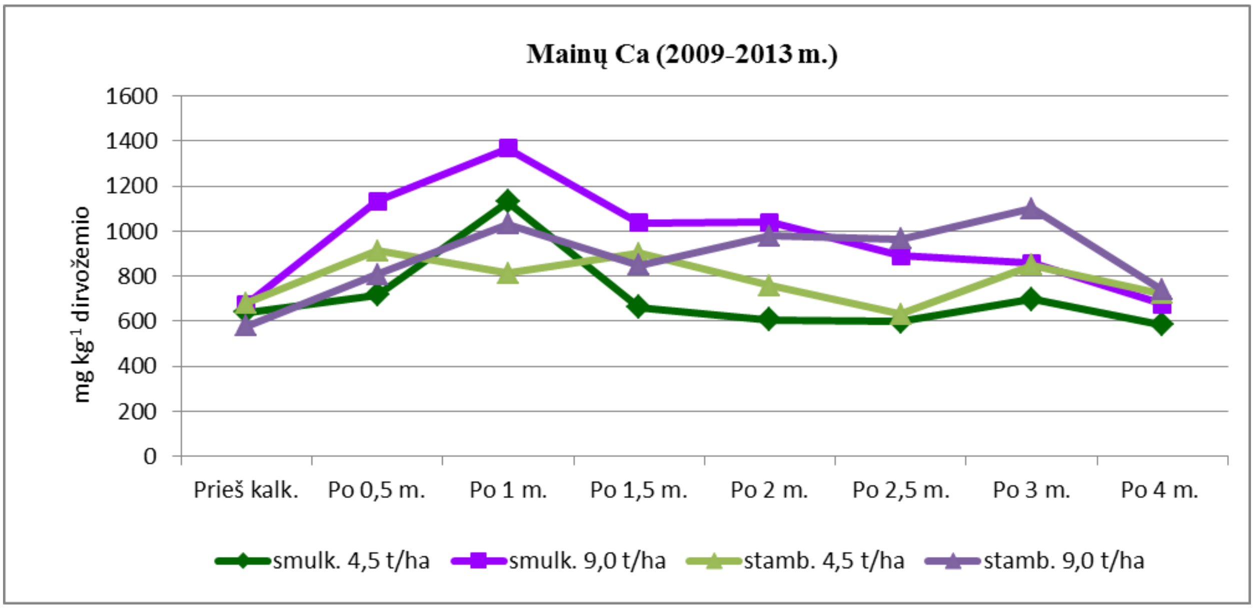
Before liming After 6 months After 1 year After 1.5 year After 2 years After 2.5 year After 3 years After 4 years
fine 4.5 t/ha fine 9.0 t/ha coarse 4.5 t/ha coarse 9.0 t/ha

Fig. 4. Effect of Kalktrąšė V on the changes in hydrolytic acidity

Application of liming substances improves soil structure, because calcium binds soil particles into stable aggregates. It also improves the water mode, activates the activity of beneficial micro organisms.

After liming, exchange calcium in the soil most of all increased thanks to fine fraction larger rate (9,0 t ha^{-1}) of the Kalktrąšė (fig. 5). Six months after inserting Kalktrąšė V, exchange Ca in the soil increased up to 1133,5 mg kg^{-1}, after one year its volume was recorded even higher: 1367,5 mg kg^{-1}. Two years after liming volume of exchange calcium stabilized in the soil and its largest volumes were found (979,5-1039,5 mg kg^{-1}) where the larger rates of both fractions were inserted. After three years exchange Ca in the soil most of all increased (up to 1101 mg kg^{-1}) thanks to the larger rate of Kalktrąšė V (9,0 t ha^{-1}) coarse fraction, where the same rate of fine fraction was applied, less exchange Ca in the soil was found: 857 mg kg^{-1}. Similar trends remain when the smaller (4,5 t ha^{-1}) rate of Kalktrąšė V was used.

Four years after the liming and after had ploughed the soil slight reduction in the exchange Ca was found. In the soil limed with the lower rates of Kalktrąšė V exchange Ca reduced down to 585 - 722 mg kg^{-1}, and in soil limed with larger rates - down to 677 -740 mg kg^{-1}.



Exchange Ca (2009-2013)

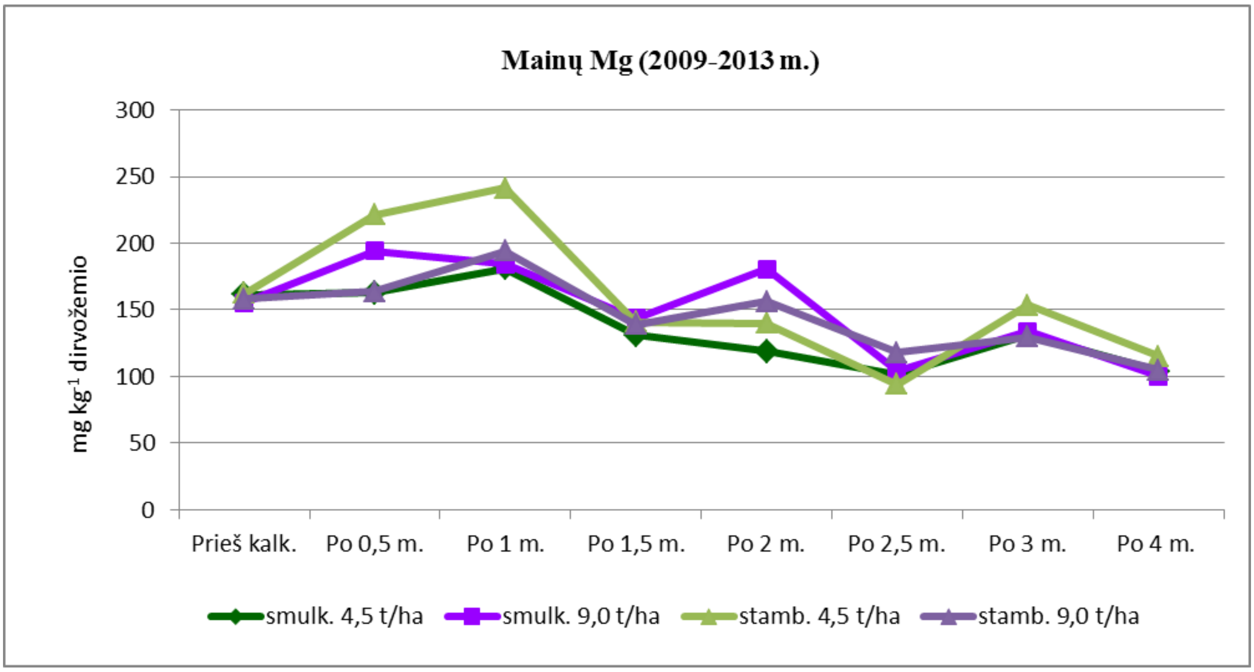
mg kg^{-1} of soil

Before liming After 6 months After 1 year After 1.5 year After 2 years After 2.5 year After 3 years After 4 years
fine 4.5 t/ha fine 9.0 t/ha coarse 4.5 t/ha coarse 9.0 t/ha

Fig. 5. Effect of Kalktrąšė V on the changes of exchange Ca in soil

Effect of Kalktrąšė V was also established for exchange magnesium (fig. 6). Volume of exchange Mg thanks to both (4,5 and 9,0 t ha^{-1}) rates and different fractions (0,01-2 and 2,0-4,0 mm) in soil grew up like exchange Ca both after one and two years. Volumes of exchange Mg three years after insertion of both rates and fractions of Kalktrąšė were similar:131 - 154 mg kg^{-1}.

Four years after liming and after ploughing the soil, volume of exchange Mg was low (up to 100 - 115 mg kg^{-1}), the soil was limed with both rates and fractions of Kalktrąšė V.



Exchange Mg (2009-2013)

mg kg^{-1} of soil

Before liming After 6 months After 1 year After 1.5 year After 2 years After 2.5 year After 3 years After 4 years fine 4.5 t/ha fine 9.0 t/ha coarse 4.5 t/ha coarse 9.0 t/ha

Fig. 6. Effect of Kalktrąšė V on the changes on exchange Mg in soil

3.5. Effect of liming substance Kalktrąšė Hum on soil's microbiological properties

In order to determine biological activity of the soil, C:N ratio was found, which shows organic mater mineralization conditions in the soil. Total biological activity was assessed according to the volume of CO_2 which evolved from the soil. The test was done 4 times during vegetation. At the same time total count or bacteria and soil micromycete (microscopic fungi) was assessed.

Spring barley crop soil shows that use of Kalktrąšė Hum slightly increased non-mineralized carbon stock in the soil (table 12). Volume of Kalktrąšė Hum did not have a larger impact. However, having applied Kalktrąšė Hum, biologic activity of the soil was almost twice as high as in non-limed soil on 29 May (barley tillering stage BBCH 21-22). During later vegetation of the plants this indicator decreases, however there are no larger differences between the trial options.

Table 12. Effect of lime substance Kalktrąšė Hum on soil's biologic properties in the spring barley crop

Option	C/N ratio *29 May*	C/N ratio *10 July*	C/N ratio *20 August*	CO_2 mg g^{-1} day^{-1} *29 May*	CO_2 mg g^{-1} day^{-1} *10 July*	CO_2 mg g^{-1} day^{-1} *20 August*	CO_2 mg g^{-1} day^{-1} *9 October*
1. Unlimed	11,14	10,36	10,86	0,0261	0,0306	0,0123	0,0229
2. Kalktrąšė Hum 1 t ha^{-1}	10,46	9,72	9,38	0,04515	0,0239	0,0126	0,0218
3. Kalktrąšė Hum 2 t ha^{-1}	9,96	9,97	10,02	0,0431	0,0330	0,0176	0,0161

While assessing changes in micro organism groups in unlimed soil, we can state that large number of the organic material decomposing ammonifying bacteria remains till the end of August (table 13). Meanwhile in the limed soil this number was significantly less. However, mineral nitrogen assimilating micro organisms quicker reach their peak in limed soil. This indicates that in these options degradation processes occurred earlier and there was more mineral nitrogen, as shown by the decrease in the C:N ratio. Reduced microscopic fungi counts in the soil also indicate the soil acidity changes using Kalktrąšė Hum.

Table 13. Effect of liming substance Kalktrąšė Hum on micro organism count in the soil of spring barley crop

Date	Option	Ammonifying bacteria count, ksv $*10^3g^{-1}$ abs.dry soil	Mineral nitrogen assimilating bacteria count ksv $*10^3g^{-1}$ abs.dry soil	Micromycete count, ksv $*10^3g^{-1}$ abs.dry soil
29 May	1. Limed	4567,22	8946,80	28,54
	2. Kalktrąšė Hum 1 t ha^{-1}	6721,22	8372,89	36,77
	3. Kalktrąšė Hum 2 t ha^{-1}	3805,54	3324,97	37,74
11 July	1. Limed	11103,4	6316,05	53,01
	2. Kalktrąšė Hum 1 t ha^{-1}	9510,34	12428,64	29,38
	3. Kalktrąšė Hum 2 t ha^{-1}	5800,80	8544,66	43,04
22 August	1. Limed	10524,58	10727,00	41,77
	2. Kalktrąšė Hum 1 t ha^{-1}	6248,36	5798,76	41,16
	3. Kalktrąšė Hum 2 t ha^{-1}	5807,40	8739,20	32,67
10 October	1. Limed	4940,17	4465,13	37,92
	2. Kalktrąšė Hum 1 t ha^{-1}	3417,50	3557,16	16,49
	3. Kalktrąšė Hum 2 t ha^{-1}	4152,10	4032,96	24,59

With the help of application of the both rates of Kalktrąšė Hum, soil biological activity in the perennial grass crop increases, though not so intensely compared with the spring barley (table 14). Biologic activity (CO_2 evolution) reaches the max values in July. In the soil with the perennial grasses, which in the spring was limed with (0,5 and 1,0 t ha^{-1}) of Kalktrąšė Hum, volume of nitrogen in soil grows during the plant vegetation (C/N ratio decreases). In the end of vegetation it remains similar in the both crops.

Table 14. Effect of liming substance Kalktrąšė Hum on soil's biological properties in the perennial grass crop

Option	C/N ratio *29 May*	C/N ratio *10 July*	C/N ratio *20 August.*	CO_2 mg g^{-1} day^{-1} *29 May*	CO_2 mg g^{-1} day^{-1} *10 July*	CO_2 mg g^{-1} day^{-1} *20 August*	CO_2 mg g^{-1} day^{-1} *9 October*
1. Unlimed	10,16	8,63	9,04	0,0178	0,02845	0,0160	0,0122
2. Kalktrąšė Hum 0,5t ha^{-1}	9,24	9,64	10,11	0,0206	0,03065	0,0234	0,0178
3. Kalktrąšė Hum 1,0t ha^{-1}	11,05	9,90	9,74	0,0265	0,03355	0,01785	0,0159

Lower biological activity in the perennial grass crop is evidenced by comparatively lower bacteria count in this soil (table 15). In the beginning of vegetation, mineral nitrogen assimilating microorganisms were more active, especially in unlimed or slightly limed with Kalktrąšė Hum soil. In the soil limed with Kalktrąšė Hum at the rate of 1,0 t ha^{-1} largest biological activity was established. Count of soil fungi in the perennial grass rhizosphere, both limed and unlimed, is larger than in the spring barley rhizosphere. The count reduces only in the end of vegetation, especially in the limed soil.

Table 15. Micro organisms in the perennial grass crop soil

Date	Option	Ammonifying bacteria count, ksv $*10^3g^{-1}$ abs.dry soil	Mineral nitrogen assimilating bacteria count ksv $*10^3g^{-1}$ abs.dry soil	Micromycete count, ksv $*10^3g^{-1}$ abs.dry soil
29 May	1. Unlimed	1425,65	18272,53	31,94
	2. Kalktrąšė Hum 0,5 t ha^{-1}	2819,14	15748,46	32,84
	3. Kalktrąšė Hum 1,0 t ha^{-1}	1486,57	8710,48	34,00
11 July	1. Unlimed	8774,46	5423,90	41,68
	2. Kalktrąšė Hum 0,5 t ha^{-1}	10084,0	5264,72	35,08
	3. Kalktrąšė Hum 1,0 t ha^{-1}	8858,97	7351,06	31,09
22 August	1. Unlimed	11392,64	12706,60	51,35
	2. Kalktrąšė Hum 0,5 t ha^{-1}	7226,10	7743,40	47,85
	3. Kalktrąšė Hum 1,0 t ha^{-1}	9219,20	7206,00	47,85
10 October	1. Unlimed	7326,90	7501,35	27,14
	2. Kalktrąšė Hum 0,5 t ha^{-1}	7695,06	7085,66	14,86
	3. Kalktrąšė Hum 1,0 t ha^{-1}	12729,36	11904,6	22,76

3.6. Application uniformity of different fractions of Kalktrąšė Hum with the help of centrifugal type fertilizer spreaders

In order to determine uniformity of spreading the granulated liming substances Kalktrąšė Hum with the help of centrifugal type fertilizer spreaders, various ratios of different fractions (fine ∅ 0,1 - 2,0 mm and coarse ∅ 2,0 - 5,0 mm) were used.

<u>Kalktrąšė Hum fraction ratios:</u>

Fine fraction 50 % + coarse fraction 50 %.
Measured from the fertilizer applicator the dropout was as follows:
4 m away 30 % fine fraction,
6-7 m away 50 % fine + 5 % coarse fraction,
9-10 m away 20 % fine + 35 % coarse fraction,
15-20 m away 60 % fine fraction.

Fine fraction 70% + coarse fraction 30%.
Measured from the fertilizer applicator the dropout was as follows:
4 m away 50 % fine fraction,
7 m away 30 % fine fraction,
9-10 m away 20 % fine + 10 % coarse fraction,
15-20 m away 80 % fine fraction.

Fine fraction 30% + coarse fraction 70%.
Measured from the fertilizer applicator the dropout was as follows:
3-4 m away 40 % fine fraction,
5-6 m away 50 % fine + 10 % coarse fraction,
9-10 m away 10 % fine + 20 % coarse fraction,
15-20 m away 80 % fine fraction.

Fine fraction 10% + coarse fraction 90%.
Measured from the fertilizer applicator the dropout was as follows:
3-4 m away 50% fine fraction,
5-6 m away 48-50 % fine + 20 coarse fraction

8 m away 2 % fine + 50 % coarse fraction,
15-20 m away 30 % coarse fraction.

Prepared different mixtures of two fractions Kalktrąšė Hum were put into suspended fertilizer spreader „Bogballe“ with centrifugal granule dispersion. The trial data obtained shows that mixtures of Kaltrąšė hum made of fine and coarse fractions are spread unevenly. Closest to the applicator (3-6 m away) most (up to 80 %) of the fine fraction ∅ 0,1 - 2,0 mm drops out, farthest (8-15 m away) most (up to 80 %) of the coarse fraction ∅ 2,0 - 5,0 mm granule drops out.

When driving the tractor through the field lime substance granules separation in the fertilizer box is not established. Liming with Kalktrąšė compounds is not desirable because the fine fraction drops out closer to the applicators, the coarse fraction drops out much further, which resulted in uneven soil liming. Unevenly limed soil is very “spotty” in relation to acidity.

CONCLUSIONS

Changes in the chemical properties of very acid (pH_{KCl} 4,4, mobile Al 77,7 mg kg^{-1}) moraine loam dystri albeluvisol prevailing in the Western Lithuania which after liming became average acid (pH_{KCl} 4,9-5,1, mobile Al 1,4-1,6 mg kg^{-1}) and plant productivity depended on rate of Kalktrąšė, fraction coarseness and the time after liming.

1. ***Single-time liming with relatively low rates*** (1 t ha^{-1} and 2 t ha^{-1}) of different (∅ 0,1-2,0 mm ∅ 2,0-5,0 mm, ∅ 5-10 mm) fractions Kalktrąšė Hum in the acidifying soil (in the period of 4 months) did not have essential effect on its acidity indicators – pH and mobile Al, hydrolytic acidity, however trend in exchange Ca and Mg growth was found. Microbiological activity of the soil in the beginning of vegetation in limed soil was twice as large, compared with unlimed soil. Liming influenced reduction of fungi count. Ratio of Kalktrąšė Hum fractions did not have influence on the changes in chemical and microbiological properties.

Largest (5,35 t ha^{-1}) barley grain yield was obtained after having limed with Kalktrąšė Hum at a rate 2 t ha^{-1} with mixture of different fractions (50 % 0,1-2,0 mm + 50 % 2,0-5,0 mm) or it was + 0,87 t ha^{-1} larger than in unlimed soil and only slightly larger (0,1 t ha^{-1}) than in the soil limed with the coarsest fraction (∅ 5-10 mm).

2. ***Single-time liming with relatively high rates*** (4,5 t ha^{-1} ir 9,0 t ha^{-1}) of Kalktrąšė V remains in effect on very acid soil indicators (pH and mobile Al, hydrolytic acidity, exchange Ca and Mg) 4 years after the liming. Soil is also to be neutralized down to pH 4,6-4,8, and having mobile aluminium volume (13,0 - 15,6 mg kg^{-1}) not yet reaching toxic level for the plants.

3. ***Annual liming of acidifying soil with relatively low rates*** (0,5 and 1 t ha^{-1}) of Kalktrąšė Hum in the rotation chain (barley with undercrop → perennial grasses I n.m.) did not have essential effect on soil acidity indicators pH and mobile Al, but the trends of increase of exchange Ca and Mg and reduction of hydrolytic acidity compared with unlimed soil were established. Microbiological activity of the soil in the beginning of vegetation was the largest in the soil limed with (1 t ha^{-1}) rate, compared with unlimed. Liming influenced reduction in microscopic fungi count.

Largest (3,85 t ha^{-1}) yield of dry matter of perennial grasses including red clover (48,4 %) was obtained in the soil limed with Kalktrąšė Hum 1 t ha^{-1} rate, compared with unlimed.

5. Mixtures of Kaltrąšė Hum made of various fractions cannot be spread evenly with the help of centrifugal type fertilizer spreaders. About 80 % of fine (∅ 0,1 - 2,0 mm) fraction drops out closest (up to 4 m) to the applicator, adequate volume of coarse (∅ 2,0 - 5,0 mm) fraction reaches furthest (up to 15 m). Such liming results in very "spotty" soil in relation to acidity.

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